Electromagnetism and Optics: Final Exam

12 December 2018

Name: _____ **Total:** **/150**

Instructions

- There are 16 questions on 10 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$$e = 1.61 \times 10^{-19}\,\text{C} \qquad q_{\text{electron}} = -e \qquad q_{\text{proton}} = +e \qquad \text{area sphere} = 4\pi r^2$$

$$m_{\text{electron}} = 9.11 \times 10^{-31}\,\text{kg} \qquad m_{\text{proton}} = 1.67 \times 10^{-27}\,\text{kg} \qquad c = 3.0 \times 10^{8}\,\text{m/s}$$

$$k = 9.0 \times 10^{9}\,\text{Nm}^2/\text{C}^2 \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\text{C}^2/\text{Nm}^2 \qquad \mu_0 = 4\pi \times 10^{-7}\,\text{T m/A}$$

Question 1

Two oppositely charged particles, labeled A and B, are placed near to each other and held fixed. A has charge $+8\,\text{C}$ and B has charge $-4\,\text{C}$. How does the *magnitude* of the force exerted by A on B, $F_{\text{A on B}}$, compare to the magnitude of the force exerted by B on A, $F_{\text{B on A}}$?

i) $F_{\text{A on B}} = \frac{1}{2}\,F_{\text{B on A}}$.
ii) $F_{\text{A on B}} = F_{\text{B on A}}$.
iii) $F_{\text{A on B}} = 2\,F_{\text{B on A}}$.
iv) $F_{\text{A on B}} = 4\,F_{\text{B on A}}$.
v) $F_{\text{A on B}} = 8\,F_{\text{B on A}}$.

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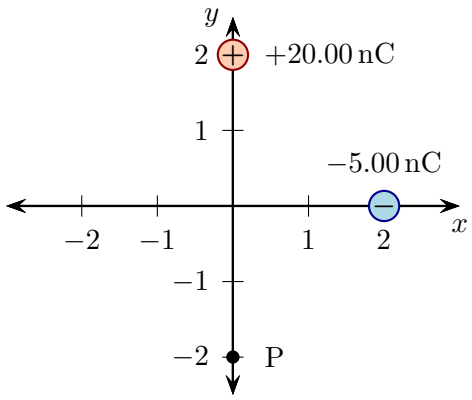
Question 2

Two charged particles are arranged as illustrated where distances are measured in meters.



a) Determine the net electric field produced by the charge arrangement at the point labeled P.

b) Determine the magnitude of the net electric field at the point labeled P.

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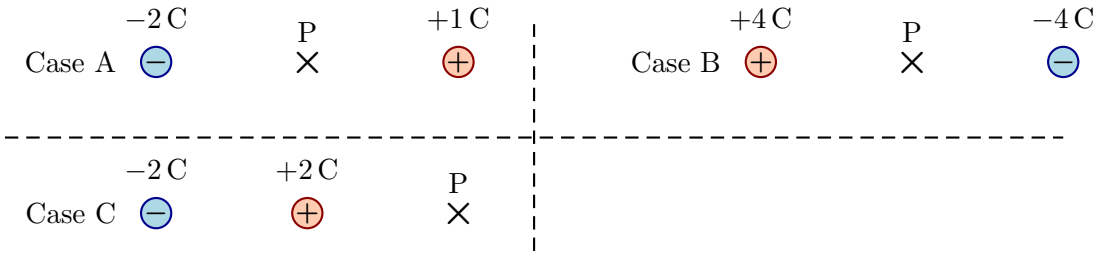
Question 3

Various arrangements of fixed charges are as illustrated.



Which of the following (choose one) represents the rank of the electric potential at the points labeled P?

i) $V_{\text{Case B}} = V_{\text{Case C}} > V_{\text{Case A}}$
ii) $V_{\text{Case B}} > V_{\text{Case C}} > V_{\text{Case A}}$
iii) $V_{\text{Case A}} > V_{\text{Case C}} > V_{\text{Case B}}$
iv) $V_{\text{Case C}} > V_{\text{Case B}} > V_{\text{Case A}}$
v) $V_{\text{Case A}} > V_{\text{Case B}} > V_{\text{Case C}}$

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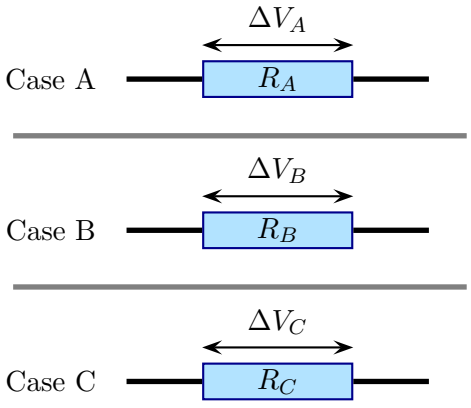
Question 4

Three resistors, of various resistances are connected to batteries of different voltages. These satisfy $\Delta V_B = 2\Delta V_A$ and $\Delta V_C = 2\Delta V_A$. Separately $R_B = 4R_A$ and $R_C = 2R_A$. Rank the powers produced by the resistors from largest to smallest, indicating equality whenever this occurs. Explain your answer.



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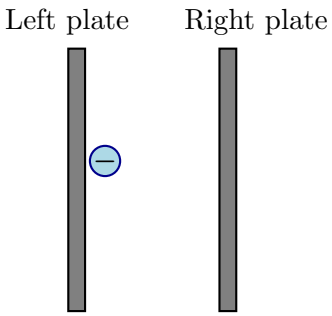
Question 5

Electrons are accelerated via an electric potential difference between two metal plates. Each electron is initially at rest on the left plate, at which the electric potential is 0 V. The potential on the right plate is such that electron moves right and attains speed 2.0×10^5 m/s at the instant just before it reaches the right plate. Determine the electric potential on the right plate which results in this motion. (Ignore any air resistance in this problem.)



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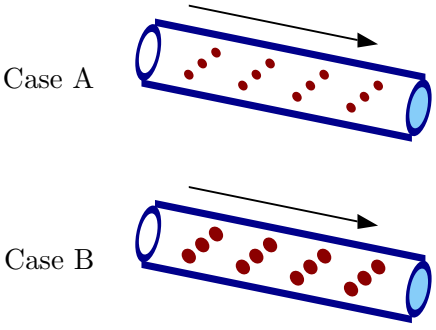
Question 6

Charged particles pass through two cylindrical sections of wire. The number of particles that emerge through the shaded end of each wire, N, is observed for a period of 10 s. In case A, each particle has charge +4.0 C and $N = 1600$. In case B, each particle has charge +12 C and $N = 800$. Which of the following (choose one) is correct regarding the current in case A, I_A, and the current in case B, I_B?



i) $I_A = 2I_B$

ii) $I_A = \frac{1}{3}I_B$

iii) $I_A = \frac{2}{3}I_B$

iv) $I_A = \frac{3}{2}I_B$

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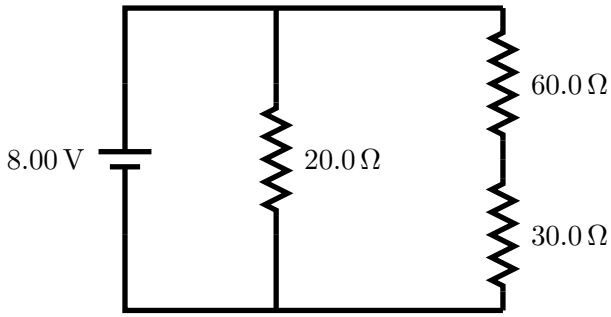
Question 7

Consider the illustrated circuit.



a) Determine the current provided by the battery.

b) Suppose that 20.0 Ω resistor is replaced by a 10.0 Ω resistor. Explain whether the current through the 60.0 Ω resistor increases, decreases or stays the same as a result of this change.

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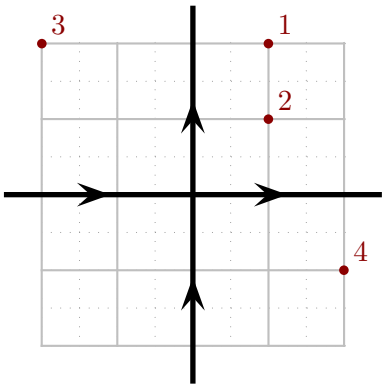
Question 8

Two infinitely long wires are oriented as illustrated and each carry the same current. Which of the following (choose one) ranks the magnitudes of the net magnetic fields at the indicated points?



i) $B_3 < B_4 = B_2 < B_1$

ii) $B_3 < B_4 = B_1 < B_2$

iii) $B_2 < B_1 < B_4 < B_3$

iv) $B_2 < B_1 < B_3 < B_4$

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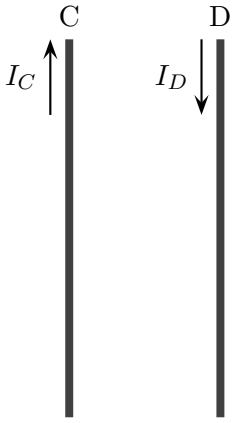
Question 9

Two parallel wires carry currents as illustrated. Wire D is infinitely long and wire C has length 2 m and is 0.25 m from wire D. Both wires carry currents of 3 A but do so in opposite directions. Determine the direction and magnitude of the magnetic field produced by wire D at the location of wire C. Use this to determine the force exerted by D on C.



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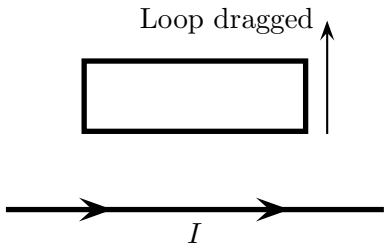
Question 10

An infinitely long wire carries a constant current, I, in the indicated direction. A rectangular loop lies in the plane of the wire and initially has no current. It is then dragged in the indicated direction. Describe whether there is a current in the loop while it is dragged and, if so, what the direction of the current is. Explain your answer.



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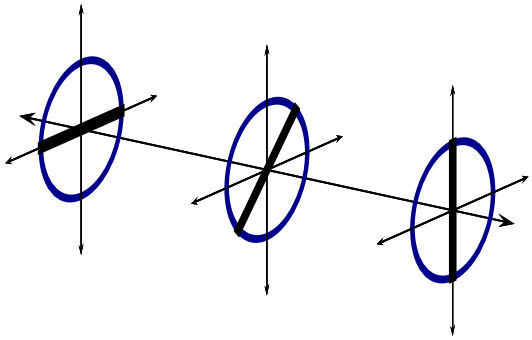
Question 11

Three linear polarizers are arranged with their transmission axes as illustrated. For the first and leftmost the axis is horizontal, for the middle the axis is midway between horizontal and vertical and for the last and rightmost it is vertical. Unpolarized light of intensity I_0 is incident from the left on the leftmost polarizer. Which of the following (choose one) best represents the intensity of the light after it emerges from the rightmost polarizer?



i) $I = 0$

ii) $I = I_0$

iii) $I = \frac{1}{2} I_0$

iv) $I = \frac{1}{4} I_0$

v) $I = \frac{1}{8} I_0$

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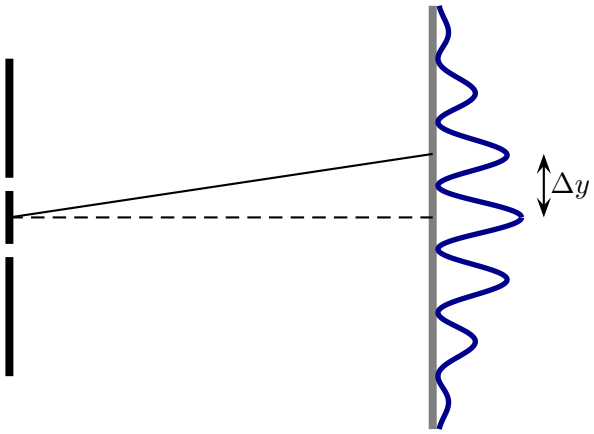
Question 12

Monochromatic light (i.e. light of one frequency) is incident on a double slit. The slit separation is 0.0500 mm. The interference pattern is projected onto a screen 2.00 m from the slits and the intensity profile is as illustrated. The distance between the first bright fringe and the central maximum is $\Delta y = 2.25$ cm. Determine the wavelength of the light.



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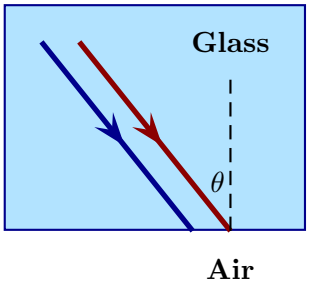
Question 13

Red and violet light rays travel parallel to each other through a glass slab toward the edge of the slab, where it meets air. While keeping the rays parallel to each other, the angle θ from the normal is increased starting from $\theta = 0°$. Initially both colors emerge into the air. As θ is increased, which, if either, of the colors will be the first to disappear from the air (i.e. no longer emerge from the bottom of the slab)? The index of refraction of the glass is 1.54 for violet light and 1.52 for red light. The index of refraction for both in air is 1.00. Explain your answer.



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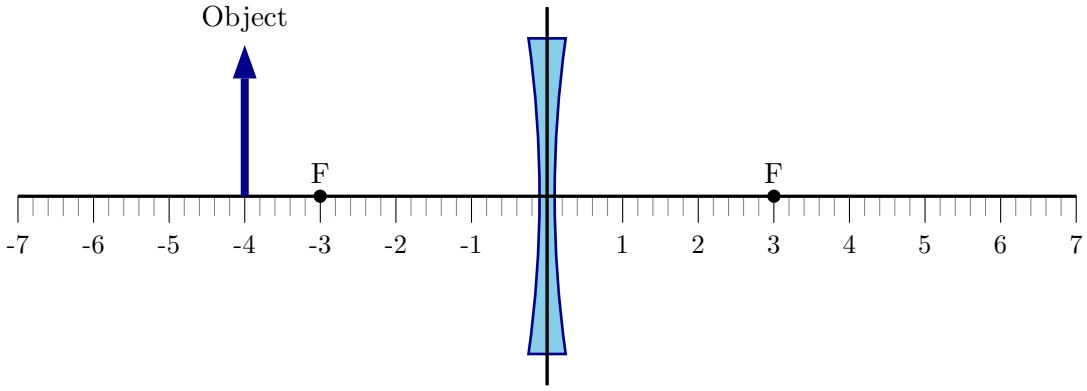
Question 14

An object, whose height is 2 cm, is placed to the left of a concave lens as illustrated. The focal points of the lens are labeled, F. The units along the horizontal axis are centimeters.



a) Trace rays as accurately as possible to indicate the image produced by the lens.

b) Determine the location and height of the image *using equations*.

c) Zog claims that it is *impossible* to use this lens to produce an enlarged image of the object using just this lens. Is Zog's claim **true or false? Explain your answer.**

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Question 15

A convex lens is constructed from glass with an index of refraction 1.55. In air (index of refraction 1.00) the lens has a focal length of 48 mm. Suppose that the lens is immersed in water (index of refraction 1.33). Which of the following (choose one) is true?

i) The focal length of the lens in water is exactly 48 mm.
ii) The focal length of the lens in water is more than 48 mm.
iii) The focal length of the lens in water is less than 48 mm.

Briefly explain your answer.

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Question 16

A string with length 1.20 m is stretched so that the speed of waves on the string is 480 m/s.

a) Determine the frequency of the standing wave that has one antinode.

b) Sketch the standing wave with three antinodes using the axis below and determine its wavelength and frequency.

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